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ATTRITION AND PROMOTION OF SCIENTIFIC AND ENGINEERING PERSONNEL IN NAVY LABORATORIES UNDER HIGH-GRADE RESTRICTIONS

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**NAVY PERSONNEL RESEARCH
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ATTRITION AND PROMOTION OF SCIENTIFIC AND ENGINEERING PERSONNEL IN NAVY LABORATORIES UNDER HIGH-GRADE RESTRICTIONS

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During Fiscal Years 1974-1981, Navy research and development (R&D) centers were restricted as to the number of high-grade (GS-13 through 15) employees they were allowed to have. To determine the impact of this restriction, the relationship between attrition and promotion was assessed using historical data. Results, which showed that the high-grade limitation is closely related to increases in professional attrition, can be used to make projections of professional attrition and form the basis for expanded analyses of civilian manpower management in the Navy.

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FOREWORD

During Fiscal Years 1974 through 1981, Navy research and development (R&D) centers were limited as to the number of high grades they could have. The Assistant Secretary of the Navy (Research, Engineering, and Systems) expressed concern that these limitations would have a long-term impact on the R&D centers and could contribute to the decline in productivity and motivation of Navy professional engineers and scientists for years to come. Accordingly, the Assistant Secretary of the Navy and the Chief of Naval Material authorized the Navy Personnel Research and Development Center to investigate the impact of these limitations on the ability of the Navy centers to perform their missions.

Results, which showed that the high-grade limitation is closely related to increases in professional attrition, can be used to make projections of professional attrition and form the basis for expanded analyses of civilian manpower management in the Navy.

JAMES F. KELLY, JR.   JAMES J. REGAN
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SUMMARY

Problem and Background

During Fiscal Years 1976-1981, Navy research and development (R&D) centers were restricted as to the number of high grades (GS-13 and above) allowed. Such restrictions limit promotion opportunity, which, in turn, results in increased attrition.

Purpose

The purpose of this effort was to determine whether and to what degree limitations in promotion to high grade affected attrition.

Approach

Regression analysis techniques were used in this study. A ratio-estimating method was used to establish the quantitative relationship between attrition and promotion rates for a given period of time.

Results

Although it was expected that the current promotion rate would affect the current attrition rate, results showed that the quantitative relationship between the promotion and attrition rates was statistically significant only when lagged data were used. The attrition rate for GS-12 professionals in a given year was related to the average promotion rate from GS-12 to GS-13 over the preceding 7 years.

The lagged promotion rate for GS-12 professionals not only affects the attrition rate for GS-12s but also the rates for GS-13 and above. The coefficient of elasticity, derived from the empirical data, show that an attrition rate for GS-12 is more sensitive to changes in the GS-12 promotion rate than to those for the GS-7 through 11 levels.

Conclusions

A method was developed to measure the responsiveness of attrition to promotion. The resulting equations empirically confirmed what has been known for some time: that limitations in high grade levels depress promotion and increase attrition. The direct impact of limitation in high grade levels on GS-13 or GS-12 promotion rate and the corresponding increase in attrition of GS-7 through 12 personnel.

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Problem

During Fiscal Years 1974 through 1981, the Navy research and development (R&D) centers operated under restrictions on the total number of permanent GS-13, 14, and 15 level employees they were allowed to have. Specifically, they were required to reduce the number of high grades by roughly 2 percent a year for the 3 years from 1978 through 1980 (Public Law 95-79). This requirement produced a steady decline in the number of high grades in the Navy R&D centers.

The former Assistant Secretary of the Navy (Research, Engineering, and Systems) expressed concern that "the long-term impacts of these constraints will have a debilitating effect on the Navy R&D establishment and, in the long run, could contribute to the professional demise of these organizations." Consequently, the Assistant Secretary of the Navy and the Chief of Navy Material authorized the Navy Personnel Research and Development Center to determine how these limitations affected the ability of the R&D centers to perform their missions.

Between FY 1974, when the annual limit on the number of high grades allowed in Department of Defense (DoD) activities was established, and FY 1980, the number of professional high-grade positions in the Navy R&D Centers reduced by 11 percent. In the same period, the attrition of Navy R&D professionals increased significantly.[1] The attrition of GS-12 scientists and engineers more than tripled during this time period.

Background

Models of attrition have been developed in the past. Clark (1977) derived a survival curve to estimate the attrition of federal civil service employees, based on length of service (LOS). Chipman (1981) applied a similar technique to a Navy research laboratory by using longitudinal data. Grinold and Marshall (1977) used transition probabilities to estimate manpower flows. Bartholomew (1973) and Bartholomew and Forbes (1979) showed how Markov processes could be modified to include the promotion rate in transition probabilities. In the area of Navy personnel planning, Charnes, Cooper, Lewis, and Niehaus (1979) embedded Markov processes in a goal programming formulation to analyze recruiting plans and equal opportunity issues.

Generally, techniques for statistical analysis of personnel flows explore the relationships between LOS and attrition. There is a lack of explicit techniques for analyzing the impact of promotion restrictions on attrition. Bartholomew and Forbes (1979) indicated that statistical methods for deriving functional forms of such relationships are still in their infancy.

Objective

The primary objective was to assess the quantitative relationship between attrition and promotion using historical data. A secondary objective was to estimate the degree of relative responsiveness of attrition to changes in promotion.

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[1] The term attrition is used to refer to persons who resign voluntarily from the federal civil service or transfer out of the Department of the Navy.

APPROACH

Underlying Theory

In economics, the concept of elasticity is used to assess the relative responsiveness of a factor to changes in another factor. There are various kinds of elasticities, such as the elasticities of demand, cost, a production function, and substitution. Among these elasticities, the elasticity of demand is most frequently used in the field of economics. In this report, the concept of the price elasticity of demand was applied in relating the responsiveness of attrition to the changes in promotion.

Sample

The Office of Personnel Management classifies GS employees into five categories: professionals, administrative, technical, clerical, and others. Since the focus of this study is on Navy R&D centers and more than 90 percent of persons in current high grades at these centers are scientists and engineers (i.e., professionals), the data used focuses exclusively on GS-5 through GS-12 professionals.

Data Source and Organization

Cross-sectional data, which describe the activities of individual persons, locations, or other units at a given point in time, can be used for estimating patterns of activities among individual units. However, they were not used in this study since it was impossible to measure the lagged[2] effects of promotion rates between years. In addition, if cross-sectional data were broken down by individual laboratory or geographic location, the resulting sample would be too small to produce any statistically meaningful results. Thus, it was decided to use the annual data available for FY 1974-1980.

The main data source for this effort was the DoD Civilian Personnel Data File maintained by the Defense Management Data Center in Monterey, California. Personnel transactions and master records were extracted for FYs 1974-1980 for the following ten naval activities:

1. David W. Taylor Naval Ship Research and Development Center, Bethesda, Maryland.
2. Naval Air Development Center, Johnsville, Pennsylvania.
3. Naval Coastal Systems Center, Panama City, Florida.
4. Naval Ocean Systems Center, San Diego, California.
5. Navy Personnel Research and Development Center, San Diego, California.
6. Naval Surface Weapons Center, Silver Spring, Maryland.
7. Naval Underwater Systems Center, Newport, Rhode Island.
8. Naval Weapons Center, China Lake, California.
9. Naval Research Laboratory, Washington, DC.
10. Naval Ocean Research and Development Activity, Bay St. Louis, Mississippi.

Work force data for the Navy labs are based on over 500,000 records. Tables 1 and 2 summarize the promotion and attrition data used in the analysis.

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[2]An employee's decision to quit may be the result of accumulated events over a long period of time. Thus, it may be more realistic to assume that attrition reacts to changes in promotion opportunity with a lagged response; that is, it may be a cumulative effect of the level of promotion opportunities in recent past years.

Table 1

Number of Promotions and Promotion Rates for GS-12 Professionals, FY 1974-1980

FY	Number of GS-12s	Number of Promotions	Average Promotion Rate for Previous 2 Years (%)	Single Year Promotion Rate (%)
1974	2,960	189	----	6.39
1975	3,131	132	----	4.22
1976	3,406	123	5.27	3.61
1977	3,644	103	3.90	2.83
1978	3,850	108	3.21	2.81
1979	3,999	152	2.82	3.80
1980	4,209	262	3.31	6.22
1981	4,130	----	----	----

Source. Computed from the DoD Civilian Personnel Data File.

Table 2

Number of Attrites and Attrition Rates for GS Professionals, FY 1974-1980

FY	Number	GS-12 Attrition	GS-12 Attrition Rate (%)	Number	GS-5-12 Attrition	GS-12 Attrition Rate (%)
1974	2,960	51	1.72	5,583	232	4.16
1975	3,130	65	2.08	5,885	231	3.93
1976	3,406	87	2.55	5,943	251	4.22
1977	3,644	125	3.43	5,945	315	5.30
1978	3,850	142	3.69	5,883	320	5.44
1979	3,999	177	4.43	5,852	395	6.75
1980	4,209	173	4.11	5,873	327	5.57
1981	4,130	---	----	5,790	---	----

Source. Computed from the DoD Civilian Personnel Data File.

Analysis

The attrition rate for GS-12 professionals in year t is defined as the number of voluntary quits for GS-12 professionals in year t (resignations and transfers outside the Department of the Navy) divided by the average[3] inventory of GS-12 professionals in year t. Similarly, the promotion rate for GS-12 professionals in year t is defined as the number of GS-12 professionals promoted to high-grade positions (GS-13) in year t divided by the average inventory of GS-12 professionals in year t.

The following two functional forms of equations were used:

1. **Simple Linear Equation**

$$S_t = a + b\bar{P}_{t-1,\ t-2}$$

where S_t denotes the attrition rate in year t,

$\bar{P}_{t-1,\ t-2}$ is the average pooled promotion rate over the past 2 years,

and a and b are parameters in the regression equation.

2. **Log-form Equation**

$$S_t = a\,(\bar{P}_{t-1,\ t-2})^b$$

Taking natural log of both sides of the equation, the following equation was obtained:

$$\text{Log}_e S_t = \log_e a + b\,\log_e(\bar{P}_{t-1,\ t-2})$$

where b represents constant elasticity of attrition.

RESULTS

The results are classified in terms of attrition models for GS-12 and GS-5 through 12 professionals, as well as a comparison of attrition elasticity for both groups.

Attrition Model for GS-12 Professionals

The empirical relationship between the attrition and promotion rates for GS-12 professionals can be expressed by the following equation:

---

[3]Average inventory of GS-12 professionals = (beginning inventory of GS-12 professionals in year t + ending inventory of GS-12 professionals in year t) ÷ 2.

$$\text{Log } S_t = 2.3844 - 0.86344 \text{ Log } \bar{P}_{t-1, \, t-2} \tag{1}$$

with R-square = 0.95

Adjusted R-square = 0.93

t for the coefficient of Log $\bar{P}_{t-1, \, t-2}$ = 7.3

where S_t represents the attrition rate for GS-12 professionals in year t, and $\bar{P}_{t-1, \, t-2}$ represents the average promotion rate for GS-12 professionals in years t-1 and t-2.

The model fits the data well. The relationship has a degree of statistical confidence of over 99 percent. It indicates that, for the GS-12 professionals, the attrition rate in a given year increases as the promotion opportunity over the previous 2 years decreases.

Attrition Model for GS-5 through 12 Professionals

The relationship between the attrition rate of GS-5 through 12 professionals and t! promotion rate for GS-12 professionals is expressed by the following equation:

$$\text{Log } S_t = 2.5371 - 0.66285 \text{ Log } \bar{P}_{t-1, \, t-2} \tag{~}$$

with R-square = 0.91

Adjusted R-square = .88

t for the coefficient of Log $\bar{P}_{t-1, \, t-2}$ = 5.4

where S_t represents the attrition rate for GS-5 through 12 professionals in year t, and $\bar{P}_{t-1, \, t-2}$ represents the average promotion rate for GS-12 professionals in years t-1 and t-2.

Again, the model fits the data well and the relationship has a degree of statistical confidence of over 99 percent. It indicates that the average promotion rate for GS-12 professionals over 2 consecutive years has an inverse relationship with the attrition rate of GS-5 through 12 professionals in the following year.

Comparison of the Attrition Elasticities for GS-12 and GS-5 through 12 Professionals

The elasticities of attrition rate are 0.86 and 0.66 for GS-12 and GS-5 through 12 professionals respectively, which indicates that the GS-12 promotion rate has a stronger effect on GS-12 attrition than on total GS-5 through 12 attrition. For example, if the average promotion rate for GS-12 professionals over the past 2 years decreased from 5 percent to 2.5 percent, a decrease of 50 percent, the current attrition rate for GS-12 professionals is estimated to increase from 2.7 percent to 4.9 percent, an inncrease of 82 percent. However, it is estimated that the attrition rate for G-5 through 12 professionals would increase from 4.3 to 6.9 percent, an increase of only 61 percent. The mathematical computations for this example are described below:

Substituting $\bar{P}_{t-1, \, t-2}$ = 5 into equation (1),

$$\log_e S_t = 2.3844 - 0.86344 \log_e (5) = 1.00.$$

The current attrition rate for GS-12 professionals becomes

$$S_t = e^{1.00} = 2.70.$$

Similarly, substituting $\bar{P}_{t-1,\,t-2} = 2.5$ into equation (1),

$$\log_e S_t = 2.38 - 0.86344 \log_e (2.5) = 1.59.$$

The attrition rate for GS-12 professionals becomes
$$S_t = e^{1.59} = 4.90.$$

Substituting $\bar{P}_{t-1,\,t-2} = 5$ into equation (2),

$$\log_e S_t = 2.54 - 0.66285 \log_e (5) = 1.47.$$

The current attrition rate for GS-5 through 12 professionals becomes

$$S_t = e^{1.47} = 4.3.$$

Similarly, substituting $\bar{P}_{t-1,\,t-2} = 2.5$ into Equation (2),

$$\log_e S_t = 2.54 - 0.66285 \log_e (2.5) = 1.93.$$

The attrition rate for GS-5 through 12 professionals will then be

$$S_t = e^{1.93} = 6.90.$$

Figure 1 shows the changes in annual promotion and attrition rates for GS-12 professionals during 1974-1980, as well as changes in their average promotion rate for the previous 2 years. Figure 2, which shows the empirical elasticities of attrition, indicates that the elasticity for GS-12 attrition is greater than that for GS-5 through 12 attrition. In Figure 3, an alternative graph was made with a logarithmic scale. The curve for GS-12 professionals is steeper than that for GS-5 through 12 professionals, indicating that the attrition elasticity for the GS-12s is greater than that for GS-5 through 12s.
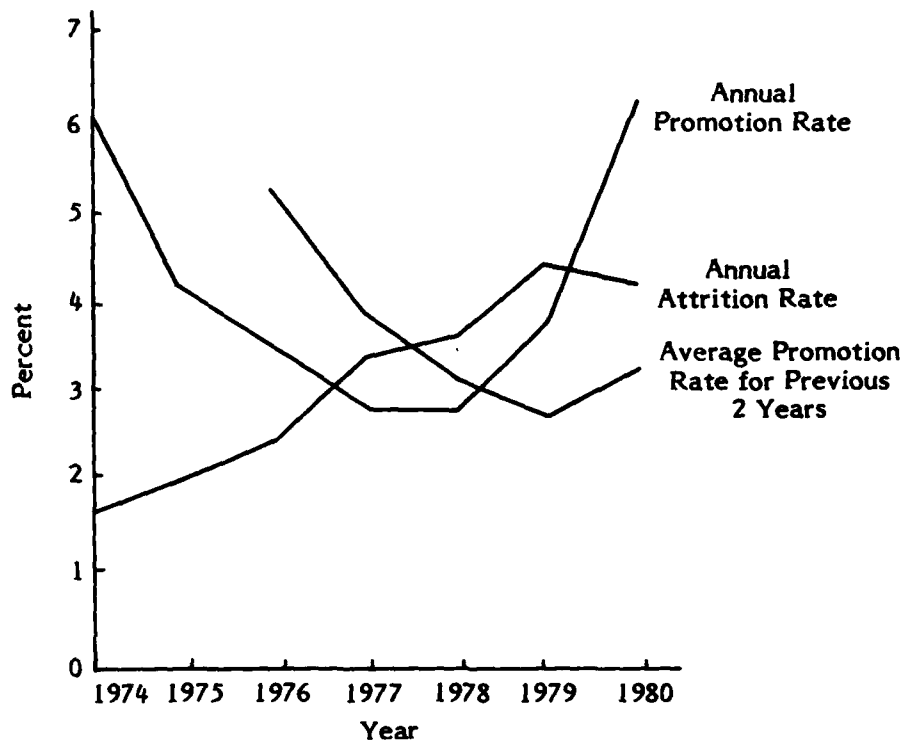
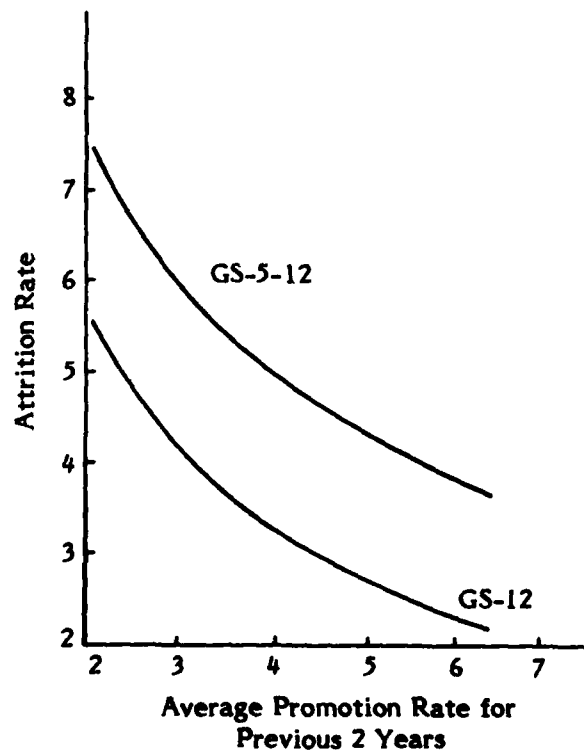Figure 1. Promotion and attrition rates for GS-12 professionals, 1974-1980.

Figure 2.   Relationship between GS-12 promotion and GS-5 through 12
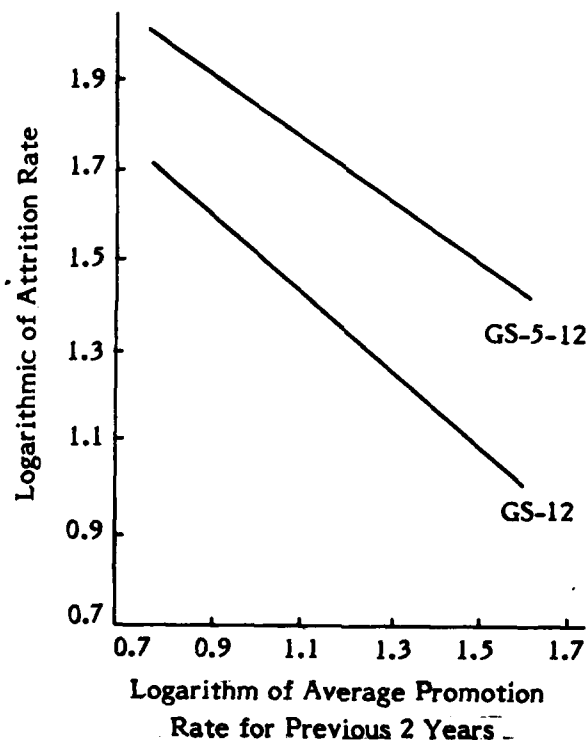attrition rates for professionals.

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Figure 3. Relationship between GS-12 promotion and GS-5 through 12
attrition rates for professionals using a logarithmic scale.

CONCLUSIONS

The feasibility of developing an analytical technique to measure the relationship
between promotion and attrition has been demonstrated. The quantitative relationship
can be used to assess the impact of limitations in the number of high-grade positions (GS-
13 and above) on the attrition of GS-5 through 12 professionals. The promotion
opportunity for GS-12 professionals has an inverse relationship with their attrition rate, in
a lagged response. Also, the promotion opportunity for GS-12 professionals has an inverse
relationship with the attrition rate of GS-5 through 12 professionals.

RECOMMENDATIONS

1. Study results should be used to assess the impact of high-grade limitations on
personnel attrition of professionals in the Navy R&D centers.

2. The approach should be applied to other occupational groups as well as other
types of Navy activities.

3. The quantification of the relationship of high-grade promotion and GS-5 through
12 attrition should be incorporated in an overall manpower planning system for Navy
civilian personnel.

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